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CURTIS LANE PALMER

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OMNIOPTICON: DESIGN ALTERNATIVES FOR A SPHERICAL PROJECTION SYSTEM

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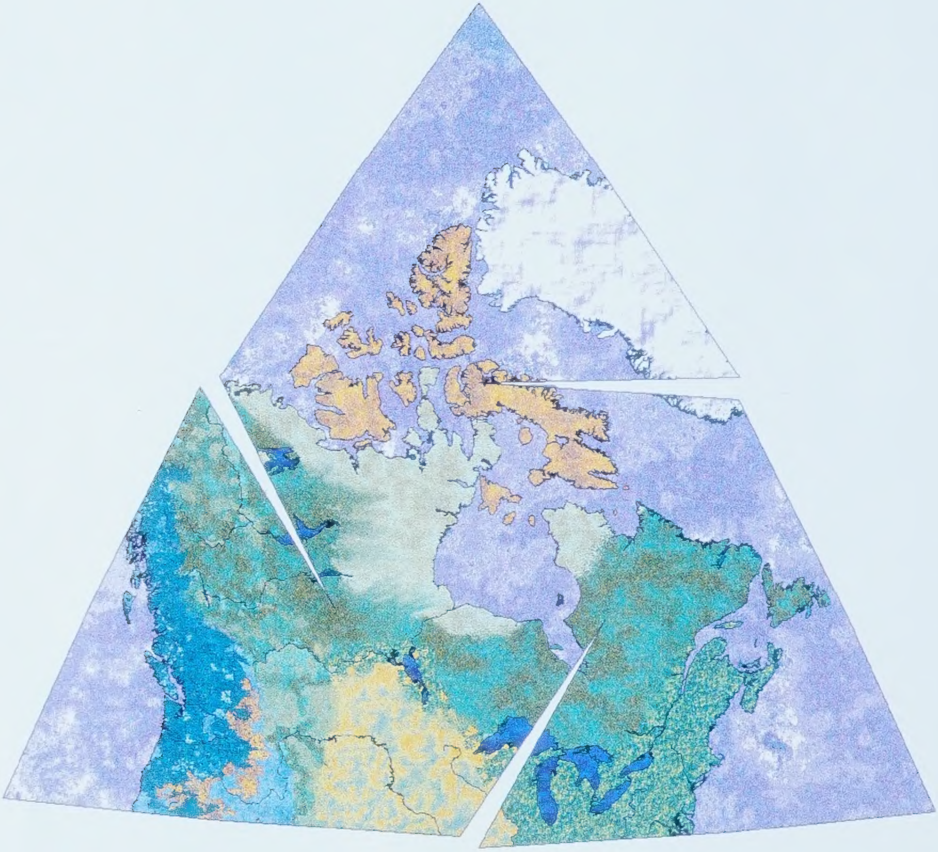

UNIVERSITY OF ALBERTA

OMNIOPTICON: Design Alternatives for a Spherical Projection System

by

Curtis Lane Palmer, B.Sc.

A written work in support of a Thesis by Project submitted to

The Faculty of Graduate Studies and Research

in partial fulfillment of the requirements for the degree of

Master of Design

in

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Department of Art and Design

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I would like to dedicate this work to my son who must inherit the apparent chaos of this world and to the late Richard Buckminster Fuller who inspired me to organize my corner of it.

ABSTRACT

This thesis explores the design of spherical displays. The thesis seeks to demonstrate that this kind of display is both desirable and achievable given the capabilities of computers and current display technology. Beginning with a review of extant display technologies, the thesis identifies additional design alternatives for the proposed display. These alternatives, represented in the exhibition, demonstrate practical means for achieving a spherical projection. Specific constructions include: a curved rear projection screen, a section of a back lit globe, a dihedral kaleidoscope, and a section of a geodesic array of projection elements.

PREFACE

This project has percolated within me for over 17 years. It began when I wrote to the late Buckminster Fuller in 1976 regarding his "Geoscope" idea. In the letter I proposed a programmable, illuminated globe constructed with Light Emitting Diodes (LEDs) for use in the classroom. Fuller's response was positive and expanded upon the need to 'read' the whole earth. To permit reading the whole earth he proposed that the globe be capable of unfolding to his Dymaxion™ projection. This projection, patented in 1946, results from the projection of geographical data onto an icosahedron.

He also suggested that the display could be controlled by manipulating 1/120 of the sphere. I regret not asking him how his control mechanism would work. LEDs proved to be too expensive at the time and my life moved on. As the field I was working in, developing industrial laser cutting systems, held much in common with the issues of the Geoscope, I was able to monitor much of the technology appropriate for developing a spherical projection system, thus keeping my dream alive.

These last two years of design education have prepared me to transform the dream into design, the results of which constitute this thesis presentation.

ACKNOWLEDGMENTS

I would like to acknowledge my patient family for permitting me the time to complete this work. Without my wife's ongoing support, the completion of this work would have been more difficult and less enjoyable. I would also like to thank my thesis supervisor, Bruce Bentz, whose criticisms kept the work within practical limits and whose support made me confident that I could accomplish what I set out to. Thanks are also due to Roly Thompson for his technical support in the construction of the various pieces. Thanks also to the Laser Job Shop for keeping the costs of so much cutting within reach of a student's budget. A special thanks goes to Dan Brevig who provided much encouragement in the final phase of this project.

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Introduction

The spherical nature of the earth, planets and stars has been deduced from experiment. Humans have been unable, until the space age, to see the world in its spherical aspect; we have, as a result, relied on instruments and maps. As the direct view of the spherical earth is limited to the astronauts, the public must continue to rely on maps and photographs to inform their global decision making. In this information age, the maps on which people rely are, increasingly, some form of electronic projection, for example, the nightly news weather map.

The problems facing humanity globally are arguably more complicated than the weather. This thesis is founded on the ideological position that solutions to these problems will only be found by a public design process. It is my opinion that the burgeoning computer networks and distance education programs will one day have the capacity to provide design and visualization software to a concerned public, actively involved with global design issues. The objective of this design thesis is to utilize available technology to develop an electronic display that presents information in a spherical form in the belief that an accurate representation of global data will inform the design process.

Design, particularly architecture, seems to begin as a constructive response to deep psychological and visceral attachments to place. Designs arise from the need to transform the environment for purposes as varied as survival and aesthetic enjoyment. Design on a global scale before the twentieth century was a rare undertaking. Typically it was the domain of the military, particularly the navy. The latter half of the twentieth century has seen the transnational corporations embrace the globe with designs for making profit. The growing awareness of the impact of consumerism upon the environment charges the individual with the responsibility to expand one's notion of place to include the home planet. This thesis proposes a design for a display that could be installed in museums, science centers and schools that could become the reference and resource for a public design utility.

When Dr. Fuller proposed the Geoscope in 1952, upon which this thesis is based, it consisted of a dynamic interactive spherical display 200 feet in diameter. This scale of display matched the then available resolution of existing aerial photographic data. The Geoscope was to be suspended outside the UN building in New York. It would have provided the custodians of world affairs with a spectacular reminder of the finite nature of our home world. Later developments included a companion flat map projection based on his Dymaxion™ map (fig. 1) for a complete view of the earth's surface.

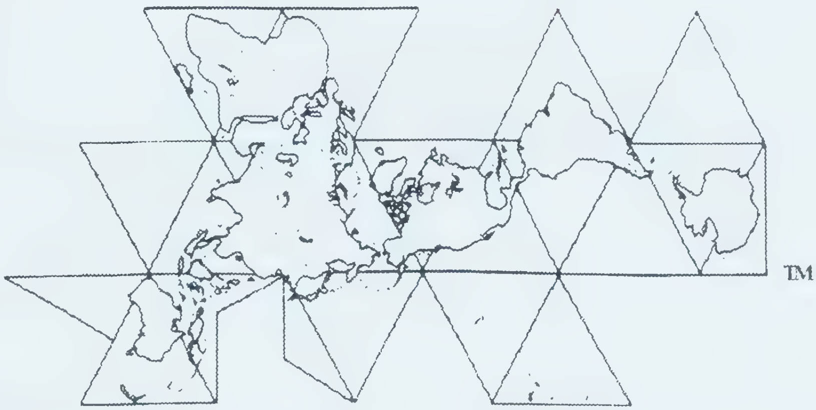

Figure 1. Dymaxion™ Map*

The Spherical Experience

Day to day we experience the world in the round. Though we live and travel in various shaped boxes, our visual, auditory and kinesthetic senses all serve to inform us of an omnidirectional or spherical environment. The celestial sphere is ultimately our home. For millennia we have placed our *axis mundi* at its center and revolve about it in our daily affairs. Technology has served to expand our horizons into the macro sphere and micro sphere. With this new knowledge we are entrusted with the care of the world for all future generations. With views so vast, problems such as preserving the environment loom ever larger and we are scrambling to find ways to visualize the solutions. Professor Charles L. Owen writes in <u>Phoenix Project: Options for a World Growing Warmer</u>,

> "Partly because the problem is potentially so massive, plausible approaches to resolving it have been difficult to visualize.... What government leaders need is ideas visualized so that they and the public can perceive both the scope of the problem and means to solve it."

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* The Fuller Projection - Dymanxion Air-Ocean World map, invented by R. Buckminster Fuller, shows our planet without any visible distortion of the relative shapes and sizes of the land and sea areas, and without any breaks in the continental contours. The word Dymaxion and the Dymaxion™ Map design are trademarks of the Buckminster Fuller Institute.

This thesis presents several designs for displays that serve to aid the visualization of global problems and solutions.

Existing Spherical Displays

Most people will be familiar with spherical displays in the form of a convex globe and concave hemispherical planetaria. If we generalize on the concept of the spherical experience discussed above, spherical displays also include the following:

- Film technologies, such as Cine 2000™ and OMNIMAX ™, that provide a concave hemispherical view screen, are available in a few centers. As yet these formats have a limited repertoire of titles.

- Head mounted displays (HMDs) have begun to impact individuals in virtual reality research facilities and video recreation centers. With appropriate software HMDs can provide both concave and convex spherical experiences.

- The entertainment industry, using a variety of film and motion control techniques, has been thrilling audiences with rides, such as Universal Studios' "Back to the Future", for years. Such rides cost many millions of dollars to produce.

- The most sophisticated technologies that provide the spherical experience are to be found in the military and commercial aviation simulator industry.

- Recent developments in military training called 'Walk In Synthetic Environments' (WISE ™ Raytheon Corp.) create ambulatory simulations for training the foot soldier.

- Computer generated geographical displays are increasingly available. They provide an effective means for displaying global data and are most commonly seen on television weather and news reports.

Functional Guidelines

For the purposes of this thesis I will concern myself only with those displays that have curved screens or, as in the case of the computer displays, visually simulate sphericity. What functions must a spherical display satisfy? Comparisons of existing displays may suggest some guidelines.

The globe is essentially a static display, unable to vary its information content over time. A recently developed puzzle globe uses magnetic jigsaw pieces to permit changes to the map, providing

a modicum of dynamism. The Geosphere™ Project has copied NASA's cloudless Earth photo mosaic onto a 6 foot diameter fiberglass sphere incorporating 37.3 million pixels. This project includes plans for larger spheres with interior fiber optic lighting for representing the Earth at night (city lights). This project also proposes to use their large globes to simulate an 'as seen from space' view for films and videos. The St. Louis Science Center has a Dymaxion Map, 70 feet wide by 35 feet tall, with computer controlled laser light shows which illustrates features of the rain forests. At the University of Minnesota, Skyline Displays Inc. has constructed its "Build a New World" Globe at 42 feet in diameter. It was painted and assembled by the collective efforts of 10,000 students from 184 schools.

Cine 2000™ and OMNIMAX™ are dynamic film displays, capable of displaying a variety of photo realistic programs. The raw information content (pixels per second) of an OMNIMAX presentation is currently the highest ever achieved due to its huge film frame size (70 mm x 15 perforations).

Planetaria are dynamic and interactive. They support a variety of projection technologies including star projectors, slide projection, Digistar™ and the now ubiquitous laser light shows.

Computer generated displays are limited to the resolution of their monitors yet when connected to world wide information databases their information potential seems unlimited and represents the most dynamic and interactive displays currently available. Recent hardware developments vastly improve three dimensional (3D) visualizations with refinements on the 3D glasses of horror movie fame. They exploit parallax effects, providing alternate views for each eye through synchronized liquid crystal filters worn as glasses.

A review of the strengths and weaknesses of these displays suggest the following functional guidelines. The display should be:

- Large enough to permit viewing by groups of people;
- High resolution in order to permit photo realism;
- Programmable so as to permit a diversity of display information;
- Dynamic in order to add the dimension of time to programs;
- Interactive, thus permitting individual and collective additions and queries to data displayed;
- Paired with a flat projection in order to display the whole sphere in one view.

Screen Formats

Several screen formats can be considered: concave or convex; spherical or hemispherical; static or unfolding; and flat. Both concave spherical and hemispherical displays provide peripheral vision enhancements although in the spherical format head or body movement is required to take in the whole scene. Seating would be limited to a few people, perhaps suspended in trapeze-like chairs. A convex spherical or hemispherical display can be considered for exhibit spaces. With these there is a loss of visual acuity along tangent lines, requiring the audience to walk around for the full impact of the display. Flat front or rear projection permits a theatre like presentation of a variety of map configurations. Unfolding displays that combine the qualities of both curved and flat displays are possible. Small screen formats such as Cathode Ray Tubes (CRTs), provide platforms for commercially available computerized atlases and encyclopedias, however, the audience is typically a single user. A concave hemispherical display, 'stick your head in style' for one user, was demonstrated at the University of Colorado in 1964. It used multiple overlay maps to show wind and ocean currents. Small convex spherical globes may be considered for the home electronics marketplace. One such product includes a touch sensitive screen that initiates an audio program of data about the location touched. An unfolding convex spherical display may be considered as a classroom educational aid as is demonstrated by the folding paper Dymaxion™ maps available from the Buckminster Fuller Institute.

For this thesis project I have chosen to develop the convex spherical screen format, primarily because of people's familiarity with globes and its potential application to community viewing and collective participation in world issues.

Display Technologies

Several display technologies may be applicable to a spherical screen format. Vector and raster displays are possible. Vector displays create images by painting with strokes of light in any given direction. They include lasers and high intensity storage CRTs (DIGISTAR). Raster displays scan an ordered array of pixels (picture elements), turning them on or off in a timed sequence. Raster CRTs are the standard projection technology in computer displays. Most cartographic databases are now in raster formats. Television and the recently developed liquid crystal display panels are raster devices. Holographic displays are theoretically possible, given the development of spatial light modulators that provide an output for computer generated holoforms (also known as kinoforms).

Head mounted displays may be the most easily adapted to displaying spherical systems. No new hardware is required to make this display. Only software development is required to create the spherical experience. The principle disadvantage of this approach is that it is a solo experience.

Light Emitting Diodes or some other discrete light source (e.g., plasma cells) in a dense packed array would be feasible for a classroom size geoscope. A resolution of 0.36 degrees of arc can be attained using commercially available LEDs 4 mm in diameter on a sphere 1/10,000,000 Earth size (4M circumference, 1.27M diameter). This pixel size represents a radius of 4 kilometers on earth and would require over 130,000 individual LED's and their support electronics. To date there is no satisfactory blue LED which would be required for full colour display. So many diodes would create significant heat that would likely reduce the mean time before failure (MTBF) of such a display, increasing operating and service costs. A display for primary school grades could be built on this discrete pixel technique using the familiar Lite Brite™ children's toy at reasonable cost.

An alternate approach to the dense packed LED display would consist of an array of LED's placed along longitudes of a spherical octahedron that would then be rotated at 30 Hz or greater; the individual LED's would be programmatically switched on or off to produce an image. This method depends greatly on the switching speed and persistence of the light source.

Some thought has been given to using optical fiber to create a display. The cost of fiber and problems of configuration make it impractical except for creating 'hot spots', such as, the Geosphere Project's use of fiber to represent city lights at night.

Liquid crystal displays (LCDs) provide one of the most promising solutions to the spherical display problem. Complete LCD globes theoretically could be produced given adequate capitalization. To develop the production of concentric glass spheres with the 6 - 10 micron spacing required by the liquid crystal fluids, photo masking of glass spheres for circuit deposition and the high pressure bonding of back plane to viewing plane would be a monumental undertaking.

A more realistic approach would be to mount several LCD projectors in a geodesic space frame which would then permit the coordinated display of data onto a spherical screen, creating a video wall in the round. For a convex display an internal light source, with a geodesic array of transmissive LCD panels and projection optics would be required. A mock up of this method of display has been developed for show. Alternately, commercially available projectors could be mounted external to a concave hemispherical screen to provide the required illumination. These projectors range in price from $2,000 to $10,000 which may be prohibitive given the large numbers of devices required to fill the sphere with an image.

The most attractive technology only now becoming available is Texas Instrument Inc.'s Digital Micromirror Device (DMD) which consists of micro machined mirrors on static RAM silicon chips. These raster devices are designed to reflect a light source programmatically onto the image plane. By altering the state of each memory cell on the chip, the mirrors, one for each pixel, are deflected up to 20 degrees, reflecting the light 'on' to the screen or 'off' to a 'dark field.' One DMD would be required for every segment of the display. Resolutions of over 1900 x 1200 (over 2 million pixels) have been achieved. Given the Geosphere Project's 37.3 million pixels, an equivalent projector could be achieved with approximately 20 DMDs. Colour is provided by synchronizing the mirror deflections with a colour wheel or switching three light sources. By using standard chip production techniques, Texas Instruments Inc. hopes to have a commercially available High Definition TV product available by 1995. Sixty-five devices fit on a silicon wafer that costs approximately $900 US to produce. If defects were nil, the cost per device would be under $15. The cost of the light sources, colour wheels and control electronics must be included. It seems likely that this would still result in a low per unit cost, which is essential when considering a spherical array of potentially hundreds of these devices (depending on radius and desired resolution). A rough mock up of this technology is included for show.

Design Objectives

For the purposes of this thesis I have chosen to present a series of constructions that illustrate several key concepts underlying the development of the Omniopticon. Specifically, the presentation consists of: a dihedral kaleidoscope, a section of a backlit geodesic globe, a sectional mock up of a geodesic projection system and a curved rear projection screen. Also included in the presentation is the geodesic dome section that was developed as a jig for manufacturing the screen component of the backlit globe.

The dihedral kaleidoscope displays computer generated graphics, which due to the internal reflections of the kaleidoscope present a three dimensional virtual image of an icosahedron (fig. 2) and its dual, the dodecahedron, to the viewer. It illustrates the principle of dynamism required by the guidelines outlined above. It is constructed from Silverlux™, a highly reflective thin film which is mounted on the orthoscheme of an icosahedron. The orthoscheme (fig. 2) is an irregular tetrahedron formed by the origin of the icosahedron and one of the 120 right triangles formed by the perpendiculars of the mid edges of the icosahedron's triangles. The orthoscheme is truncated at the plane of contact with a computer screen. A computer program repetitively draws images at the truncation plane which, with the resulting reflections, create aesthetic patterns for viewing. Using

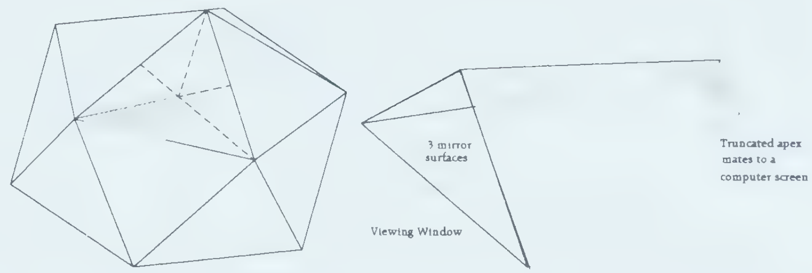

Figure 2. Icosahedron showing the derivation of its Orthoscheme

approximately half of the computer monitor's resolution of 1024 x 768 pixels, 393,216 pixels will be reflected 60 times giving a total of over 23 million pixels in view. The image is necessarily symmetrical.

The backlit geodesic globe section serves to link the project with its cartographic function. This construction is essentially a luminare consisting of an irregular tetrahedron formed by the origin of a spherical icosahedron and three of its edges (1/20 sphere). One of the four faces of the tetrahedron is fitted with an acrylic geodesic window consisting of 16 triangles. (fig. 3) The three remaining faces are constructed of Medium Density Fiberboard (MDF). The interior faces are lined with Silverlux mirror film on 0.02 aluminum. A triangular bracket to support the socket is placed near the origin and wired through a hole near the origin. The angles at which the mirrors connect serve to produce symmetrical reflections which, in turn, produce the illusion of an icosahedron floating inside a geodesic dome. This illusion will not be visible as the geodesic window will be covered with a map of North America. The whole assembly is supported by a metal frame formed from three great circles of the icosahedron coincident with the edges of the luminare.

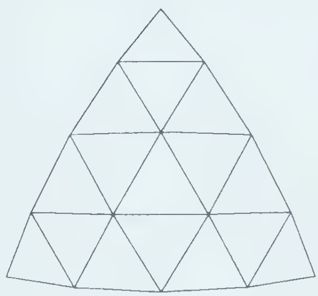

Figure 3. 1/20 of Four Frequency Geodesic Dome

The sectional mock up of a geodesic projection system serves to show the configuration of two different projection schemes. One scheme uses a 35 mm slide to represent a transmissive liquid crystal display panel. The other scheme uses a fiber optic bundle to roughly simulate a Digital Micromirror Device. The projection apparatus and screen are assembled on concentric geodesic frames that incorporate 1/30th of a sphere.

The curved rear projection screen is included to display a range of images created during the design process. It uses a computer controlled Liquid Crystal Display panel to highlight the intended use of this display technology for the development of the spherical display.

Design Development

Throughout the development of these constructions the computer, running a variety of software applications and programming languages, was used. AutoCAD was used to create the drawings required for subsequent laser cutting of parts for the jig. Dome geometry was developed mathematically using Lotus 123™. Turbo Pascal™ and AutoLisp™ programs were created to extract cartographic data from the Micro World Database™ into an AutoCAD format. Pascal was also used to create the graphic displays for the dihedral kaleidoscope. Corel Photo-Paint™ was used to colour the map. Much of my design effort was spent in mastering these programs.

The construction of each artifact has had its own development milestones and pitfalls. The dihedral kaleidoscope depended upon finding an inexpensive reflective material that could be applied to the orthoscheme form at the desired scale. The orthoscheme geometry was easily constructed from an icosahedron[1] drawn in AutoCAD. The overall proportions for the display were chosen to fit a 14 inch Hyundai monitor. To achieve a successful mating of kaleidoscope to computer screen a frame was constructed of ash 1x2s that supports the monitor and kaleidoscope at a thirty degree viewing angle. The curvature of the monitor screen was incorporated into the kaleidoscope frame. This curvature consequently imparts a curvature to the image, making it appear somewhat stellate (starlike). This suggests that other screen geometries would provide images which range from concave to planar to spherical.

The curved rear projection screen is constructed from a commercially available Plexiglas skylight mounted in a simple fir frame. Slides of images created during the design process will be projected upon it, illustrating the advantages of large scale display for group interaction, as well as the actual use of an LCD panel for projection.

[1]Drawing the icosahedron and domes in general, has for years been a challenge with every CAD package I have encountered. I have subsequently found an easy construction method based on the icosahedron's intrinsic golden mean proportionality. The vertices of the icosahedron are coincident with the vertices of three golden rectangles arranged parallel to the planes of the XYZ Cartesian axes.

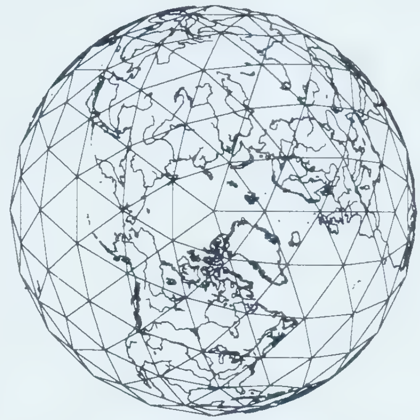

Figure 4. Four Frequency Geodesic Dome Overlaid on Globe

The section of a backlit geodesic globe (fig. 4) and the mock up of a geodesic projection system comprise the bulk of the three dimensional design effort. Here the construction details have been worked out in detail. Originally it was thought that a satisfactory projection system was possible using an icosahedral array of 20 projection elements composed of the digital micromirror device (DMD) and associated optics and light sources. A review of the optical principles involved showed that focal lengths and magnification requirements would place light source and projection lenses on top of one another. Reducing the required image magnification entailed repositioning the projection elements out from the center of the dome. This was achieved by increasing the frequency of the geodesic breakdown. The breakdown[2] chosen for the backlit globe produces satisfactory sphericity although it increases the device count from 20 to 320. This increases cost and control problems but vastly increases the potential resolution of the display.

Another breakdown based on a rhombic triacontahedron (triacon) was chosen for the sectional mockup. This breakdown achieves similar sphericity with reduced part inventory but it also reduces triangle symmetry. Although the precise optical arrangement of the spherical display will be determined by a more detailed optical analysis, it was felt that this would be satisfactory for illustration purposes and the objectives of the thesis would not be compromised by developing a more conceptual approach.

With this shift in focus, the design process concentrated on the development of an illuminated geodesic globe. Cost and time constraints made it apparent that a full globe was unnecessary to illustrate the design, therefore a module consisting of 1/20th of a sphere has been developed for show.

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[2]Frequency in geodesic construction refers to the number of subdivisions of the principle polyhedral triangle (PPT). In this work the principle polyhedron is the icosahedron with f=1. With f=4 each edge of the icosahedral triangle is divided into 4 parts and a triangular grid of 16 triangles is overlaid through these points on the triangles. The intersections of the grid are mathematically projected to the surface of the circumsphere producing a set of 6 unique edge lengths, 6 faces and 4 hubs.

This module is composed of 16 bonded Plexiglas triangular panels forming a geodesic window, mounted in a tetrahedral frame with an internal light source and a coloured plot of North America adhered to its surface. To bond these panels it was necessary to construct a matching geodesic jig. The jig consists of: 30 struts, 15 hubs (figs. 5 & 6) and 16 inserts precision cut by laser from 12 gauge steel. There are four different hubs each made of five pieces: a top cap, bottom cap, spacer with a nut and bolt to hold them together. The hubs are designed to connect the struts as well as provide a ledge for the inserts that are keyed with the Plexiglas panels for alignment. There are six different struts and inserts. (figs. 7 & 8) The jig (fig. 9) was also used experimentally to align and weld 16 steel panels and as a mold for vacuum forming another window from Vivak PET, a transparent thermoform plastic.

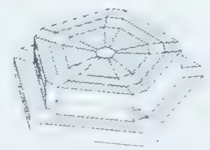

Figure 5. Hub Configuration

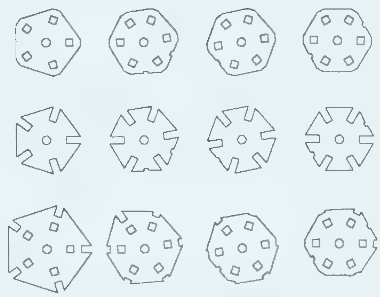

Figure 6. Hub Components

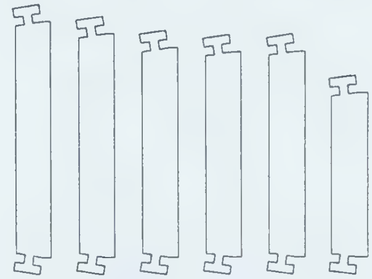

Figure 7. Struts

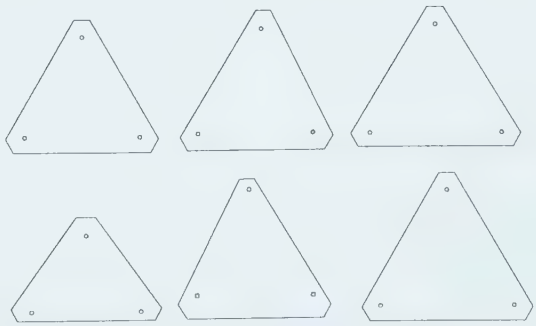

Figure 8. Inserts

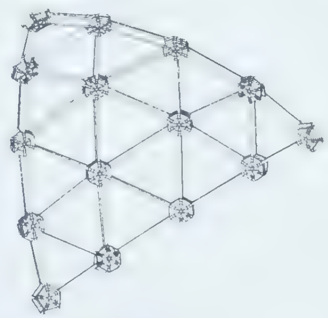

Figure 9. Jig

The projector mock up consists of four concentric geodesic sections (1/30th sphere): screen, projection optics, light modulators, and light sources. The part inventory for each geodesic shell of the projection system consists of four different struts and hubs and two faces. Two hundred forty triangles are required for a full sphere from which eight were chosen for display purposes. These eight triangles show two of the symmetry units of the triacon with its characteristic diamond shape. Two of the eight triangles are complete with projection optics, light sources and light modulators. For demonstration purposes the most likely candidates for the computer controlled light modulators, liquid crystal panels and digital micromirror devices, have been respectively represented by a 35 mm slide and a fiber optic bundle. The screen is made from folded Mylar supported on 4 rods radially projecting from the optic support frame; the optics are 8x Agfa style loupes; the frame is made from laser cut masonite and the light sources are 20 watt and 50 watt quartz halogen bulbs. The light source for the optical fiber bundle is housed in a tetrahedral 'integrating sphere' that serves to collect the light and direct it along the fibers. This light collector is mated to an aluminum tetrahedron housing the power supplies for the lights. Together they form a tetrahedral dipyramid. The whole assembly is mounted on a mahogany frame. A complete geodesic dome of the same geometry and radius of the optic support frame is also presented in order to visually link the mock up to its spherical form.

Synergetic vs. Cartesian Geometry

Fuller's Synergetics has provided the foundations for my design and systems explorations. It has also caused a great deal of frustration. Every time I attempted to develop a model of a polyhedral device other than a cube, the computer and the machine tools at my disposal were designed for typically Cartesian operations with for example presets for 45 and 90 degrees. Principles of structure which are simple and elegant in Synergetics took on a significant procedural component when reduced to practice in the form of construction, program or drawing. This consumed a great deal of time. If, as Fuller claims, synergetic geometry is an accurate model of the universe, society's ongoing dependence on the Cartesian abstraction is obstructing our understanding and utilization of natural processes much like the QWERTY keyboard slows the modern typist.

The dependence of the Omniopticon on triangulation suggests that the construction and addressing of LCD and DMD devices should be modeled after a trilateral rather than traditional rectilinear raster formats, which would see significant quantities of pixels unused around the image generating triangle. Figure 10 shows a selection of possible pixel packing and addressing schemes

which could be used in DMD chip and LCD manufacture. This also leads to speculation whether there would be advantages to circuit design based on alternate topologies.

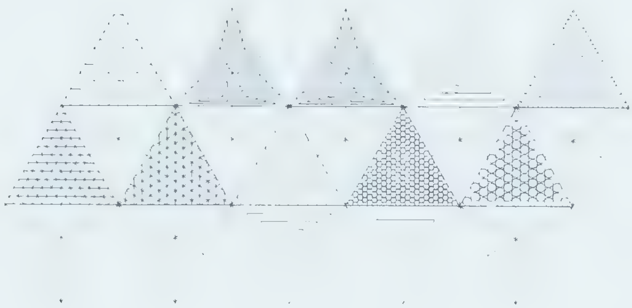

Figure 10. Trilateral Raster Schemes

Polyhedra

In the development of the Omniopticon I graphically explored the platonic and archimedean solids for use as the underlying form of the display. I developed a drawing database in AutoCAD of the five platonic and thirteen archimedean solids which because of these structures' intrinsic symmetries and AutoCAD's poor three dimensional visualization algorithms, appeared on screen and in print as mandala like tesselations of polygons (fig. 10). These I used as source material for developing a series of coloured prints some of which I have included in my thesis presentation both as projected images and as printed works. This colour study underscored a recurring design problem concerning the images to be presented on the Omniopticon. What colours should be displayed to represent the data on display?

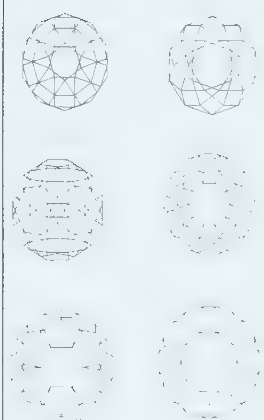

Figure 11. Some Archimedean Solids in plan view

Colour

To date all of the images I have developed for show use arbitrary colour. One possible colour scheme for representing the material world would consist of the spectra of the constituent elements. Another scheme, used by the Geosphere Project, utilizes colours recorded by satellite photography. The 'false colour' maps used by remote sensing operations permits colour to be chosen specifically

for the data to be displayed, whether it is the health of our forests, the ozone hole or the patterns of human migration. With 24 bit colour provided by today's graphic processors, it is possible to assign unique colour to over 16 million different data elements for display. The capacity of these processors provide cartographers with the latitude to enhance the practice of their art.

Computer Resources

The choice of palette and resolution significantly impacts the computer resources required for the display. The image of North America developed for show used 24 bit colour and 150 dots per inch (dpi). It required over a megabyte of computer storage. A full sphere only 12 inches in radius at this resolution would require over 20 megabytes. The computational requirements required for the animation of such a display is beyond the capacities of today's desktop computers. A complete systems analysis is required to identify the computer resources needed for the display.

Conclusion

The Omniopticon has proven to be a subject with seemingly endless design possibilities. I believe that this work has demonstrated, as it set out to do, that a spherical display is both achievable and desirable. If so, the door is opened to what Fuller called the "collective phase" of design whereby the Omniopticon would be subject to a "design and development undertaking - involving plural authorship and specialization of full-time associates." [Fuller 1963] I look forward to pursuing this possibility.

Appendix: Panopticon vs. Omniopticon

When naming the design for this thesis I was influenced by the technical term for a slide projector, stereopticon. It seemed natural to preface '-opticon' with the Latin 'omni-', meaning all or everywhere, as I intend to project images in all directions at once. Subsequent reading of The Birth of the Prison, by Michel Foucault, revealed the "Panopticon" to have the synonymous Greek root 'pan'. Foucault maintains that the Panopticon, an architectural solution to 19th century prison design, also became the model for bureaucratic control of schools, factories and hospitals.

Foucault's analysis of Bentham's design methodology links the panoptic principle with the politics of exclusion which, for Foucault, is symbolized by the historical response by society, to the leper and the plague. The panoptic view was for the 'guardian'; those guarded were excluded from society and from each other.

> "at the periphery , an annular building; at the centre, a tower; this tower is pierced with wide windows that open onto the inner side of the ring; the peripheric building is divided into cells, each of which extends the whole width of the building; they have two windows, one on the inside, corresponding to the windows of the tower; the other, on the outside, allows the light to cross the cell from one end to the other. All that is needed, then, is to place a supervisor in a central tower and to shut up in each cell a madman, a patient, a condemned man, a worker or a schoolboy. By the effect of back lighting, one can observe from the tower standing out precisely against the light, the small captive shadows in the cells of the periphery. They are like so many cages, so many small theatres, in which each actor is alone, perfectly individualized and constantly visible. The panoptic mechanism arranges spatial unities that make it possible to see constantly and to recognize immediately. ... The plague stricken town, traversed throughout with hierarchy, surveillance, observation, writing; the town immobilized by the functioning of an extensive power that bears in a distinct way over all individual bodies - this is the utopia of the perfectly governed city. ... all the authorities exercising individual control, function according to a double mode; binary division and branding ... and that of coercive assignment...The dualistic mechanisms of exclusion." [Foucault]

In Virtual Communities, Howard Rheingold writes positively about how the early forms of the information highway had a community building effect, due in part to an enhancement of the democratic process that the speed and accuracy with which information is exchanged electronically. Computer assisted participatory democracy has promise. Yet, he also warns of a rise of panopticism. With the advent of the information super highway there is a potential for an electronic guardian to monitor our every move. Like the inmates in Bentham's prison we will have no privacy. To some extent this is already the case. Every time one uses a credit card, one's consumption is noted in

some demographic database and one is targeted for yet more junk mail. The consumer society is reinforced at the expense of the environment.

Predictions that societies will collapse due to environmental degradation are rife. For the powerful, the potential for collapse may justify the use of the information highway to implement draconian controls that bear 'in a distinct way over all individual bodies '. How a balance between privacy and freedom of information is found will be a problem for the 21st Century. The prospect for 24 hour a day on-line circuses where each user is 'alone, perfectly individualized and constantly visible,' to an electronic guardian, needs to be offset by 24 hour a day on-line access to the means to solve real world problems. What I would call a design utility.

The environmental decay that we witness is coincident with the rise of, what Willem H. Vanderburg calls in The Growth of Minds and Culture, the "first universal culture". There is the distinct possibility that the first universal culture could also be humanity's last. The primary characteristics of this universal culture are its acceptance of modern technology and its predominant exposure to built environments rather than natural environments. It seems that cultural evolution would proceed in this context, apparently divorced from nature, were it not for signs of environmental crisis. The illusion of the universal culture's separation from nature is nowhere more apparent than the landfill site. Here also we find another manifestation of the boundary between public and private. One person's waste is everybody else's problem. This boundary I would argue is a consequence of the exclusionary politics and mechanistic world view that motivated the development of the Panopticon.

In contrast to these motivations, the rise in the late twentieth century of the systems paradigm which stresses "wholeness of being" [Vanderburg], underlies the motivation for the Omniopticon. It incorporates a politics of inclusion and a relativistic world view. The Omniopticon seeks to 'arrange spatial unities that make it possible to see constantly and to recognize immediately,' the consequences of human activity on a global scale and in public view; that we may create and recreate the built environment responsibly. All of us are both guardian and madman. Instead of a "privileged place for experiments on men" [Foucault], as with the Panopticon, the Omniopticon is planned as a gathering place for differentiating "reality and reality as it is known" [Vanderburg]. It is a public forum whereby the first universal culture can evolve to a second universal culture which embraces nature and technology by design.

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Slides

1. Typical hub components and a typical strut of the Jig.

2. Close up of Jig assembly - hubs and struts.

3. Jig assembly without inserts.

4. Jig inserts.

5. Jig assembly with inserts.

6. Geodesic section - experimentally welded panels.

7. Map sections glued to vacuum formed geodesic section.

8. Globe Section Lamp - view 1.

9. Globe Section Lamp - view 2.

10. Interior of Globe Section Lamp showing icosahedral reflections.

11. Dihedral Kaleidoscope assembly - view 1.

12. Dihedral Kaleidoscope assembly - view 2.

13. Typical image formed within the kaleidoscope.

14. Projector Mock Up - view 1.

15. Projector Mock Up - view 2.

16. Geodesic dome (4 frequency class II method 3 - 27.25" diameter).

17. Bubble Screen (wide angle view).